

THE OPTICAL PROPERTIES OF IDEAL SOLUTION IMMERSION LIQUIDS

M. J. BUEGER, *Massachusetts Institute of Technology,
Cambridge, Mass.*

ABSTRACT

Immersion technique requires a series of liquid standards of continuously variable optical properties. These are provided by mixing end members of different index. One particular case of miscible liquid pairs, known as ideal solutions, provides simple relations between composition and optical properties. In an ideal solution system, index is a linear function of composition, and it is shown, from this and other considerations, that it follows that the temperature coefficient and dispersion are linear in composition and also in index. This enables the index of the entire system of liquid solutions at all wavelengths to be given on a single straight line chart.

INTRODUCTION

Emmons has proposed sets of liquids^{1,2,3} which are suited to the requirements of the variation methods, in which absolutely reproducible optical properties are necessary. So long as this constancy is attainable and the liquids are reasonably convenient to use, and so long as liquids are available so that their variation ranges overlap somewhat, the optical properties of individual liquids and their mutual relationships are immaterial. When the liquid standards are to be used for ordinary immersion technique, however, there are other considerations worth taking into account in designing a set of liquids. For ordinary technique, a set of liquids ought to have the following property which, incidentally, would add convenience to the liquids to be used in the double variation technique if optical constancy could be simultaneously secured:

¹ R. C. Emmons, The double dispersion method of mineral determination (preliminary paper): *Am. Mineral.*, **13**, 1928, pp. 504-515.

² R. C. Emmons, The double variation method of refractive index determination (second paper): *Am. Mineral.*, **14**, 1929, pp. 414-426.

³ R. C. Emmons, A set of thirty immersion media: *Am. Mineral.*, **14**, 1929, pp. 482-483.

The primary desideratum is that adjacent liquids should have nearly, if not quite, identical optical properties other than index. For example, in some of the older sets of immersion liquids made up of various oils, cinnamon oil gave trouble because of its enormous dispersion. The colored fringes formed in white light by oblique illumination tests always gave erroneous impressions, in comparison with adjacent liquids, as to the difference between liquid and crystal indices. In other words, with this kind of a series of immersion liquids, the nearness to a match in indices cannot be reliably inferred from the oblique illumination test. The most desirable situation would be to have a series of liquids of different refractions but equal dispersions and temperature coefficients. Unfortunately, however, substances with low indices as a rule have relatively low dispersions while substances with high indices have high dispersions. To a less marked extent the same relationship holds with regard to temperature coefficients as well. An ideal immersion series is therefore not attainable. It is not difficult, however, to make a series of liquids of different refractions, having dispersions and temperature coefficients continuously variable with refractive index. This allows comparable oblique illumination tests with liquids of not too widely separated index, a feature not only of convenience to the veteran crystallographer, but also of the greatest importance to the beginning student, who has plenty to occupy his attention without having to keep in mind the details of a discontinuous dispersion series. This requirement calls for a series of liquids, in its simplest form, made by mixing two miscible end members of as widely different index as feasible. In the following section, the relationship between properties in such a series will be given.

THE OPTICAL PROPERTIES OF IDEAL SOLUTIONS

IDEAL SOLUTIONS

In a system of liquid solutions derived by dissolving two mutually miscible end members in one another, the physical properties of intermediate mixtures are necessarily continuous functions of composition. The form of the function may vary from case to case. One very simple, particular kind of solution system may, however, be distinguished; this is to be designated an *ideal solution* system. An ideal solution system is one in which the form of the above function is linear. In other words, in a series of individual ideal

solutions made from two end members, the properties of intermediate members are straight line functions of composition. The physical significance of this is that in an ideal solution, the molecules of each of the constituents function as if they were independent, and properties are additive. Fundamentally, a molecule, placed in a series of environments, will behave as if it were independent of its environment if these are chemically and physically similar, and give rise to the same "background" interaction with the molecule in question. Hence mixtures of chemically very similar liquids give rise to ideal solutions.

REFRACTIVE INDEX

The refractive indices of possible intermediate members of an ideal liquid-liquid solution system are indicated graphically in Fig. 1. The two end members *A*, and *B*, have indices n_A and n_B respectively. The index n_x of any mixture of *A* and *B* depends on the relative proportions by volume, V_A and V_B , of *A* and *B* present in the total volume V . From the similar triangles, the precise relation can be seen to be:

$$\frac{n_x - n_A}{n_B - n_A} = \frac{V_B}{V_B + V_A} = \frac{V_B}{V} \quad (1)$$

or

$$n_x = n_A + \frac{V_B}{V_B + V_A}(n_B - n_A). \quad (2)$$

Given, then, two end members of indices n_A and n_B , and a bottle holding V cc. of liquid, it is possible to calculate the volume of *A* and the volume of *B* to add to it to fill it with a liquid of index n_x . The volume is usually set at about 16 cc. by the standard double stoppered bottles (which have an average volume of 20 cc. but vary between 18–25 cc.). In the original standardization procedure, the volumes V_A and V_B are conveniently run directly into the bottle from a couple of sensitive burets. The bottle is then stoppered with the first stopper, shaken thoroughly, and the index of the liquid checked exactly on a refractometer.

Due to the impossibility of reading a buret closer than a drop, sufficient precision can be had by graphical calculation. This is conveniently accomplished by drawing Fig. 1 to a large scale on graph paper so that the base line is equal to 16 cc. The volumes of *A* and *B* to be added for any liquid *X* are then given directly.

If the end members are miscible but do not form ideal solutions, the properties of intermediate members lie on a curve such as the dotted line in Fig. 1. If a graph is available beforehand, intermediate members may be made up rapidly.

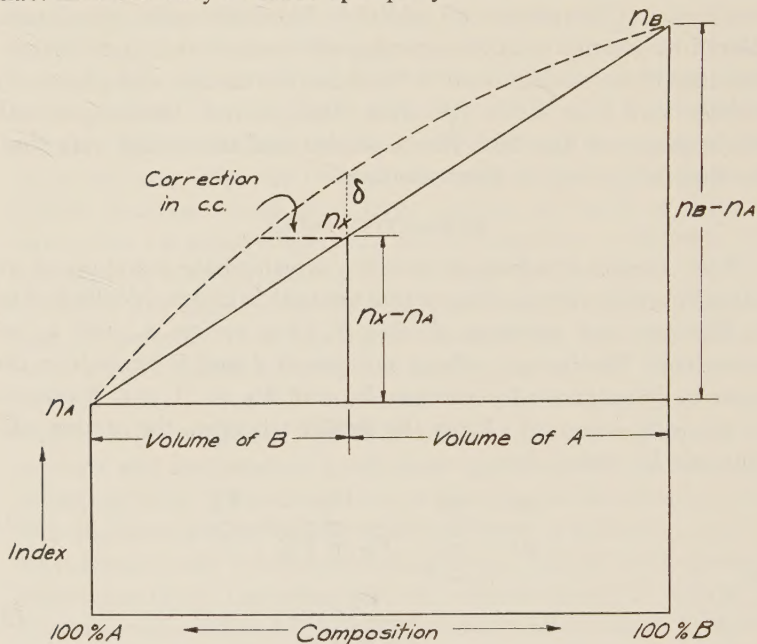


FIG. 1

TEMPERATURE COEFFICIENT

In Fig. 1, the index line n_A n_x n_B applies, of course, to indices taken at any wavelength or at any temperature, because, for ideal solutions, all properties are straight line functions of composition without restriction. It follows that the vertical *difference* between the straight line representing indices, say, at 20°C., and the straight line representing indices at 21°C., will be a third straight line which might be labelled $n_{20} - n_{21}$. That is to say, the temperature coefficient of refractive index, dn/dT , is a linear function of composition. Since composition and index are linear with respect to one another, and composition and temperature coefficient are linear with respect to one another, it follows that index and temperature coefficient are also linearly related. In other words, the

temperature coefficient of refractive index of an ideal solution system is a straight line function of index.

Composition can be measured by either weight or volume methods. The first is accurate but inconvenient, and the second is convenient but limited by the accuracy of the buret. In practical cases, a total volume of 16 cc. is dealt with, and a buret can be run and read to about 0.1 cc. This gives an accuracy of the order of 1%. Index, however, can be rapidly and certainly read to about 0.0001. For an index range of the order of $1.5000 - 1.4000 = .1000$, an accuracy of the order of 0.1% can be attained. Therefore, in the making and standardization of index liquids, it is desirable to make rough approximations to correct value by volume and final checks by means of refractive index directly. It is for this reason that attention is given above to the interchangeability of composition and index as a coordinate with which to compare temperature coefficient (and dispersion, see below).

DISPERSION

Similarly, for any constant temperature, a straight line would represent the index as a function of composition at some wavelength λ_1 , while another straight line would represent it at another wavelength λ_2 . The difference between these two indices is a third straight line relating $n_{\lambda_1} - n_{\lambda_2}$ to composition. In other words, the dispersion $\Delta n / \Delta \lambda$ is a linear function of composition, and following the reasoning in the last section, it is also a straight line function of index. This, of course, applies not only to the arbitrary dispersion $n_F - n_C$, but to any other dispersion whatever. It will be convenient to use the dispersion $n_x - n_D$ in certain practical cases to be discussed.

The dispersion of a substance can be derived from any one of several formulas which give refractive index as a function of wavelength. For the present purpose, the empirical Hartmann formula, which represents indices well, will be employed. This is:

$$n = n_0 + \frac{c}{(\lambda_0 - \lambda)^k} \quad (3)$$

where n is the index desired for wavelength λ , and where n_0 is the index at some arbitrary standard wavelength λ_0 ; k is a constant which is practically invariable from substance to substance. For glass, it is usually taken as 1.2. Certainly it can be taken as iden-

tical for two liquids which form near-ideal solutions. It is this circumstance which brings about a very great convenience in the use of an ideal solution system for immersion media.

Relation (3) may be expressed:

$$n - n_0 = \frac{c}{(\lambda_0 - \lambda)^k} \quad (4)$$

or more simply:

$$- \Delta n_A = \frac{c}{(\Delta \lambda)^k} \quad (5)$$

where Δn_A is the change in refractive index of a liquid, A , as measured from some standard index, corresponding with the change in wavelength, $\Delta \lambda$, from some standard wavelength. This is illustrated in Fig. 2. A similar relation holds for any second liquid, B , of the same ideal solution system for the same change in wavelength, $\Delta \lambda$:

$$- \Delta n_B = \frac{c'}{(\Delta \lambda)^k} \quad (6)$$

Dividing (6) by (5) gives:

$$\frac{\Delta n_B}{\Delta n_A} = \frac{c'}{c} \quad (7)$$

That is to say, at any wavelength whatever, the ordinate of the dispersion curve of a liquid, B , is a magnified version of the ordinate of the dispersion curve of another liquid, A , the magnification ratio being c'/c . Consequently, all dispersion curves are identical with one another except for the scale of the ordinates. This, of course, is not generally true for any two substances whatever, but it is true so long as the constant k in the Hartmann dispersion formula is really a constant. This is the case with pair of liquids capable of forming ideal solutions, as will be demonstrated with an actual example in a following paper.⁴

The foregoing relationships may now be combined into a single diagram from which the dispersion of any solution of an ideal solution system may be read, having given the index of the solution in question for any wavelength. Since the effective wavelength of the

⁴ R. D. Butler, Immersion liquids of intermediate refraction, to follow.

light from a sodium flame has come to be the standard for which refractive indices are usually given, both in the literature and on certain calibrated refractometers (say, the Abbe refractometers, which are so popular), n_D , will be chosen as the standard n_0 of equation (3), which thus makes $\lambda_0 = \lambda_D$. The upper left drawing of Fig. 2 shows the dispersion curves of two end member liquids, A and B . According to the preceding discussion, the height of the ordinate at any wavelength referred to the height of the ordinate at the standard wavelength, λ_D , as zero, is the same in each liquid except for the scale of the ordinate system. Hence all rays drawn through the ordinates of corresponding points on the curves of liquids A and B will meet in a point which may be termed the *projection* point. According to the discussion the dispersion of any intermediate member made by mixing the two end members, A and B , is also a linear function of the index of the mixture. If the scale of the distance between the planes of the dispersion curves of A and B (Fig. 2) is given the dimension of index, then the ray system through the ordinates of the dispersion curves for liquids A and B will intersect the plane of the dispersion curve of the mixture and determine a dispersion curve whose ordinate scale is proportional to the distance of the new plane from the point of projection. Thus the end members and all possible intermediate members of an ideal solution system have dispersion curves whose corresponding ordinates are proportional to a constant plus n_D , the constant being the distance of the point of projection (in terms of refractive index) to the index of the lower index end member.

For practical use, this space diagram must be drawn in two dimensions. The construction is indicated in the lower half of Fig. 2. The wavelength scale is obtained from a carefully explored dispersion curve near the high index end of the system. A second partially explored curve locates a few points which determine the projection point. The wavelength scale is most accurately constructed by plotting the indices of points of the well explored curve, not on ordinary graph paper, but on special Hartmann dispersion formula graph paper,⁵ on which dispersion curves come out as straight lines (see Fig. 6 of reference 4). This allows very accurate interpolation and especially extrapolation for the construction of scales. Actually there is a slight curve in the dispersion lines even on this paper,

⁵ Apparently unknown in America, but obtainable from Germany through E. Leitz, Inc., 60 East 10th St., New York.

due probably to the fact that the constant k is not quite correct for liquids. This error, however, can be eliminated by smoothing in a curve which is very near to the straight line but which fits the experimental points a little better.

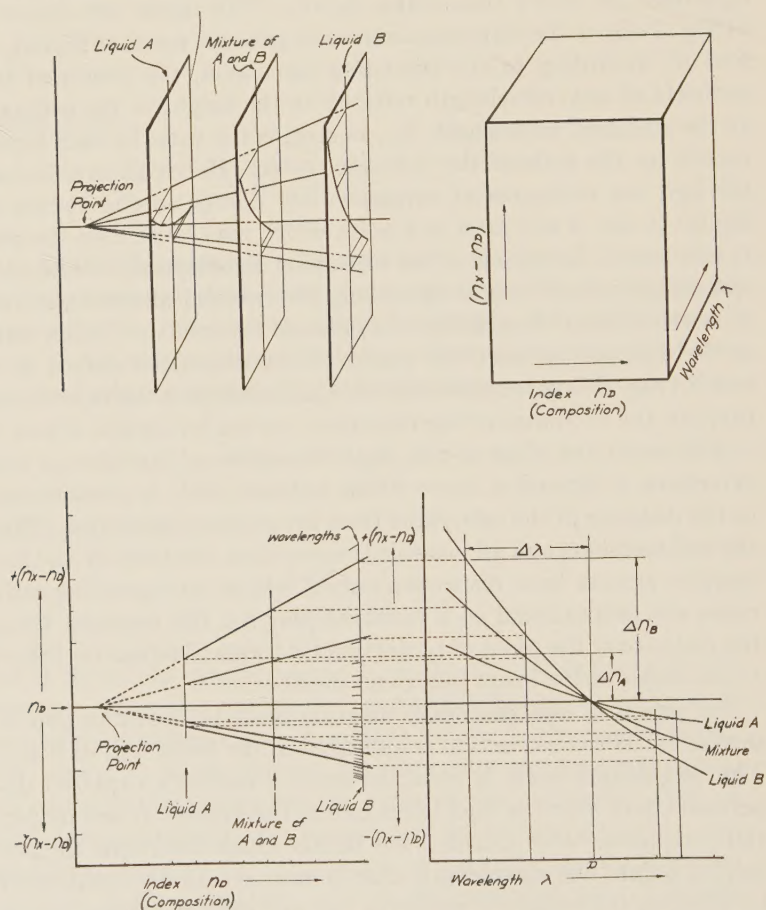


FIG. 2

To use the diagram, proceed as follows: Given a liquid in the system, whose index has been determined for sodium light at some standard temperature, to find its index at any other wavelength: On the lower left diagram (which is the only useful part of the diagram, after it has been constructed), draw a vertical line corre-

sponding with the index n_D . Lay a straight edge from the projection point to the point on the wavelength scale on the right hand side

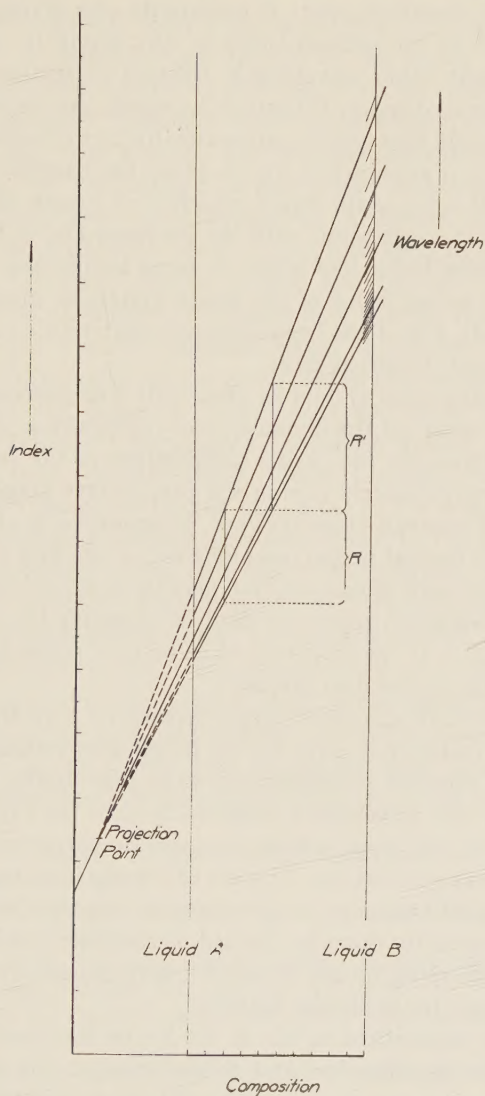


FIG. 3

of the diagram, corresponding to the wavelength for which the index is required. The ordinate of the point of intersection of the

line and the straight edge, as read on the left border, gives the correction to be algebraically added to n_D to give the required index.

The above described chart is essentially one giving *corrections* to be applied to the sodium index of any liquid in order to get its index at any other wavelength. Being a correction chart it is very economical of space. If desired, however, the corrections may be made to apply themselves automatically by extending the chart and modifying it as shown in Fig. 3. Here, the baseline is not zero, but the actual index of the liquid, which is, of course, variable with composition. It corresponds with the previous Fig. 2, then, except that the sodium index line which is there horizontal, is arranged to follow the actual index of the liquid system as given in Fig. 1. In other words, Fig. 2 has been sheared counterclockwise until the n_D line acquires its actual slant.

The following point should be observed: The abscissae of Fig. 3 are correctly assigned the dimensions of composition. As explained previously, however, the actual composition of the liquid is only dealt with approximately during the preliminary stages of mixing the liquids. From this stage forward, composition is of no interest whatever, for optical properties alone are of use and measureable. Therefore, the units of composition may be omitted from the chart, and the n_D line given whatever slant is necessary for the accuracy of index desired. If the scale of indices is to be made accurate, this chart takes up a great deal of space.

From this chart, the index range covered by a given liquid with wavelength variation is given by the length of a vertical line at the composition abscissa corresponding with that liquid, which is intercepted by the wavelength range to be used. In Fig. 3, R is the index range of the liquid whose composition corresponds with the left hand short vertical line. If a set of liquids is to be designed so that each liquid begins its range where its neighbor leaves off, this can be conveniently done by the aid of the chart, as indicated by the non-overlapping ranges R and R' . Any desired overlap can be easily arranged for in similar fashion.

The writer is indebted to Mr. R. D. Butler for drawing the illustrations to his specification. In a following paper, by R. D. Butler, the optical properties of an actual ideal solution series will be described.

METALLIC MINERALS IN ANHYDRITE CAP ROCK, WINNFIELD SALT DOME, LOUISIANA

VIRGIL E. BARNES, *Bureau of Economic Geology, Austin, Texas.*

The Winnfield salt dome is located in Winn Parish, north-central Louisiana. A shaft sunk to the salt by the Carey Salt Company penetrates a zone containing metallic minerals. Specimens of these minerals collected from the mine dump were transferred to the writer by Mr. Paul Weaver, who has also contributed helpful suggestions in the preparation of this paper. Other specimens from the mine dump were collected later by the writer. Facilities for the study of these minerals were kindly furnished by the Bureau of Economic Geology, Austin, Texas, and by the Department of Geology, State College of Washington, Pullman, Washington.

Only a few metallic minerals have, heretofore, been recorded from American salt domes. A green copper mineral is recorded from the Hockley salt dome by Teas.¹ Hauerite (MnS_2) is reported by Wolf² and Hanna.³ Chalcopyrite, sphalerite, galena, and pyrite are mentioned from the Belle Isle salt dome, Louisiana, by Veatch⁴ and Vaughan.⁵ This completes the list, so far as the writer is aware, of metallic minerals described from salt domes. Of the minerals found during the present study only pyrite and chalcopyrite have been previously reported. Besides pyrite and chalcopyrite, native arsenic, chalcocite, enargite, and realgar are present.

These minerals are found at a place on the mine dump indicating that they are from the basal portion of the anhydrite. The same cap rock sequence, as found on many other American salt domes, is penetrated in the Carey Salt Company shaft. Thicknesses and depths of the materials penetrated are given in the following table.

¹ Teas, L. P., Hockley salt shaft, Harris County, Texas: *Am. Assoc. Pet. Geol. Bull.*, vol. 15, p. 465, 1931.

² Wolf, A. G., Hauerite in a salt dome cap rock: *Am. Assoc. Pet. Geol. Bull.*, vol. 10, pp. 531-532, 1926.

³ Hanna, M. A., A second record of hauerite associated with Gulf Coast salt domes: *Am. Assoc. Pet. Geol. Bull.*, vol. 13, p. 177, 1929.

⁴ Veatch, A. C., The Five Islands: *Geol. Sur. of Louisiana*, Rept. for 1899, pp. 223-226.

⁵ Vaughan, F. E., The Five Islands, Louisiana: Geology of salt dome oil fields, *Am. Assoc. Pet. Geol.*, pp. 386-388, 1926.

RECORD OF CAREY SALT COMPANY SHAFT, WINNFELD, LA.

<i>Formations</i>	<i>Thickness Feet</i>	<i>Depth Feet</i>
Loam.....	2	0
Clay.....	33	2
Limestone—"Calcite cap".....	70	35
Gypsum—"Gypsum cap".....	25	105
Anhydrite—"Anhydrite cap".....	308	130
Salt	?	438

The metallic minerals have formed along parallel planes producing a distinct banding in the anhydrite. One mineralized layer is composed of native arsenic spheroids as much as a quarter of an inch in diameter. Other bands are composed predominantly of individual minerals, suggesting that selective replacement has taken place along lines of banding in the anhydrite, which in the mineralized zone shows no pronounced transverse breaks. This banding may correspond to flowage lines, rather than to bedding of a sedimentary type.

The native arsenic in the Winnfield specimens is a rather soft, brittle, light-gray, dull metallic mineral that tarnishes dark gray to nearly black, has a subconchoidal fracture, exhibits some evidence of colloform structure, and polishes to a white, smooth surface. A white arsenic trioxide sublimate and a garlic odor are given off if a specimen is placed on charcoal and touched by a blowpipe flame. Sublimation continues after the flame is removed until all the arsenic is consumed and leaves a very porous, magnetic ash containing copper. The iron and copper contained in the mineral probably cause the arsenic to oxidize in this peculiar manner.

Characteristic etch tests show that a bluish-gray mineral, associated with the native arsenic, is chalcocite. Chalcopyrite, a very abundant mineral in many specimens, is easily recognized by its characteristic color and softness. Pyrite is present in a few specimens. A mineral was encountered that stains black with potassium cyanide and is negative towards all other etching reagents. As this mineral is not separable from native arsenic and chalcocite, a qualitative analysis of material containing all three minerals was made. The analysis shows that arsenic, copper, and sulphur are abundant; also some antimony, as well as a trace of iron are present. The mineral is probably enargite (Cu_3AsS_4) containing some antimony.

A very soft, porous, dark-colored material surrounded by native arsenic, and a similar brownish substance surrounded and veined by chalcopyrite, reacted briskly with nitric acid. These substances are probably residues of sooty chalcocite and limonite, which were formed by the leaching of impure native arsenic.

Realgar is rather abundant in some specimens, and some orpiment also is present. The orpiment appears to have formed since the specimens were exposed to light and air. This exposure, according to Winchell,⁶ permits a change to take place from realgar to orpiment and arsenolite (As_2O_3).

Green and blue copper minerals are prevalent on the surfaces of these specimens, but are not observed on fresh fractures. They probably formed while the specimens were on the mine dump in contact with chlorides, sulphates, and the damp Gulf Coast air. The rapidity of weathering may be judged, if the slightly weathered specimens, which were collected by Mr. Weaver, are compared with the highly weathered ones collected by the writer a few months later.

The non-metallic minerals were not especially studied. Anhydrite is the dominant mineral present. A few dolomite rhombs attached to the sides of gypsum filled tension cracks, and two very small druses of quartz in the anhydrite were exposed by polishing. Native sulphur was not seen.

The metallic minerals are located along anhydrite grain boundaries (Figs. 1-4) and show definitely that the anhydrite is replaced. Native arsenic was the first metallic mineral deposited. Replacement of native arsenic by chalcocite (Fig. 1), enargite (Fig. 2), and chalcopyrite has largely obscured the relationship of anhydrite to native arsenic. However, the scanty evidence present indicates that native arsenic replaces anhydrite. Corroded chalcocite fragments surrounded by enargite show that chalcocite preceded the enargite. Simultaneous deposition of enargite and chalcopyrite is indicated by the relationship shown in Fig. 4. Pyrite, which is younger than anhydrite, is not associated with the other metallic minerals, consequently its age relation to them is indeterminable. After deposition of metallic sulphides had entirely ceased tensional cracks formed across the mineralized bands. Realgar crystals and dolomite rhombs were deposited along the walls of these cracks,

⁶ Winchell, A. N., *Elements of Optical Mineralogy*, pt. II, p. 22, *New York*, 1927.

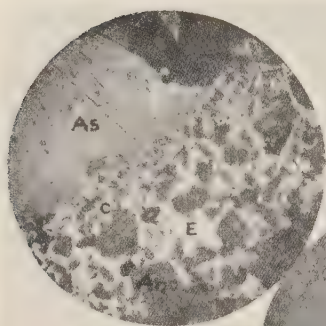


FIG. 1

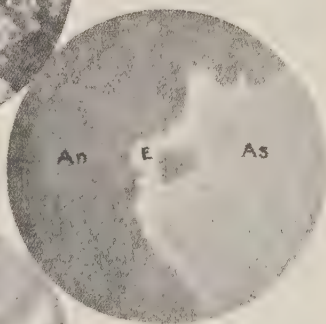


FIG. 2

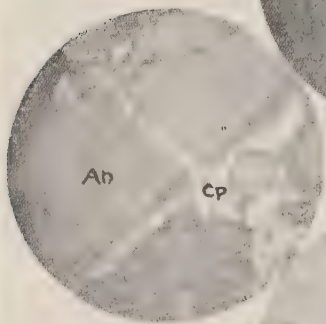


FIG. 3

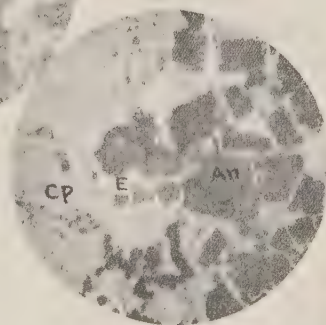


FIG. 4

PLATE I

The symbols on the photomicrographs are as follows: As—native arsenic; C—chalcocite; E—enargite; Cp—chalcopyrite; and An—anhydrite. The magnification is uniformly forty diameters.

FIG. 1. The edge of a native arsenic granule is replaced by chalcocite and enargite. Enargite is later than chalcocite, and all three minerals are later than anhydrite.

FIG. 2. The edge of a native arsenic granule is replaced by enargite. Both minerals are later than anhydrite.

FIG. 3. A chalcopyrite veinlet crosses a crystal of anhydrite, and chalcopyrite replaces other anhydrite grains along their boundaries.

FIG. 4. The chalcopyrite and enargite situated along anhydrite grain boundaries are related in such a manner that simultaneous deposition is indicated.

and the remaining space was filled by gypsum. Native arsenic was probably leached to form realgar, leaving the contained impurities as a residue of sooty chalcocite and limonite.

The source of these minerals is conjectural. Enargite is thought by American writers to be hypogene. European writers, however, have expressed the view that it may be supergene. Chalcopyrite is predominantly hypogene, and a few occurrences are undoubtedly supergene. Chalcocite in most deposits is supergene, but in a few it is hypogene. The evidence suggests a hypogene origin for this mineral assemblage; yet a supergene origin may be possible.

The orthorhombic variety of chalcocite, which forms at a temperature below 91°C., is indicated by the etched cleavage. The chalcocite, therefore, could not have crystallized at greater depths from the earth's surface than about seventy-five hundred feet, providing the present geothermal gradient observed in the salt-dome areas existed at the time these minerals were deposited. This depth is near that given by Lindgren⁷ for the central portion of the mesothermal zone. These minerals then, if hypogene, evidently belong to either the mesothermal zone or to the overlying surficial epithermal zone of ore deposition. Epithermal and mesothermal mineral deposits are probably largely derived from ascending mineralized solutions from magma basins or congealing batholithic masses.

The mineral paragenesis in a mesothermal deposit is usually pyrite, enargite, chalcopyrite, and chalcocite, deposited in the order named. The order for the Winnfield minerals is chalcocite and enargite-chalcopyrite. This change in order may be caused by the host rock, which is entirely different from that in any other deposit described.

In summarizing, it may be said that the metallic minerals of the Winnfield salt dome are *epigenetic*, and were deposited in the order: native arsenic, chalcocite, and enargite-chalcopyrite. Realgar crystals and dolomite rhombs, enclosed by gypsum, fill tensional cracks that formed across the brittle metallic mineral bands. The realgar is a secondary mineral crystallized from material nearby, probably from impure native arsenic, part of which was leached, leaving the contained impurities as a porous mass of sooty chalcocite and limonite.

⁷ Lindgren, Waldemar, Mineral Deposits, p. 598, New York, 1928.

The primary chalcocite probably is the orthorhombic variety which crystallizes below 91°C . If this be true, and the geothermal gradient at the time these minerals were deposited was the same as at present, the anhydrite was within seventy-five hundred feet from the surface at the time these minerals were introduced. These minerals belong probably to either the mesothermal or epithermal group of mineral deposits, which connotes an origin from some magmatic source.

BAVENITE: SYMMETRY, UNIT CELL

C. J. KSANDA AND H. E. MERWIN, *Geophysical Laboratory*.

The finding of beryllium in bavenite has led to a new formula.¹ Considerations of symmetry are now clearing up discrepancies in the descriptions of physical properties.

Laue photographs were taken in three rectangular directions. The one with x -rays incident along the vertical axis is reproduced in Fig. 1. This, and photographs normal to (100) and (010), showed



FIG. 1. Laue photograph of bavenite taken with a narrow beam of x -rays nearly parallel to the c -axis, at a distance of 5 cm. from crystal to plate. Owing to the minute size of the crystal and its composition an extremely long exposure, 58 k.v.-23 m.a., was necessary; a universal type, tungsten anticathode, x -ray tube was used.

the two-fold symmetry required of orthorhombic crystals. The obvious doubling of spots accords with goniometric observations kindly made by Dr. George Tunell that vertical striations of the crystal blades are accompanied by slight lack of parallelism of adjoining parts.

¹ W. T. Schaller and J. G. Fairchild, *Am. Mineral.*, 17, 409, 1932.

Oscillation spectrum photographs were obtained for the same three directions with Cu-K α radiation ($\lambda=1.538 \text{ \AA}$), from an unstriated crystal about 0.05 mm. thick and 0.3 mm. wide. With the

TABLE 1
FORMS AND ANGLES OF BAVENITE

New, orthorhombic, orientation					Old, monoclinic, orientation
Forms	Calculated		Observed*		Forms*
	ϕ	ρ	ϕ	ρ	
<i>a</i> (100)	90°00'	90°00'	90°00'	90°00'	<i>b</i> (010)
<i>b</i> (010)	0 00	90 00	2 33	90 00	<i>a</i> (100)
<i>m</i> (110)	50 0	90 00	49 29	90 00	<i>m</i> (110)
<i>l</i> (120)	30 48	90 00	28 23	90 00	<i>l</i> (210)
<i>t</i> (012)	0 00	12 06	0 00	11 52	<i>c</i> (001)
<i>u</i> (032)	0 00	32 46	0 00	33 57	<i>u</i> (101)
<i>d</i> (052)	0 00	47 0	0 00	48 38	<i>d</i> (201)
<i>e</i> (112)	50 0	18 27	52 41	19 01	<i>e</i> (012)

* Adapted from Schaller's table, many of the measurements could be only roughly approximate.

same crystal a rotation photograph and an equator layer-line photograph were taken with a Weissenberg *x*-ray goniometer using Cr-K α radiation ($\lambda=2.285 \text{ \AA}$), from a metal *x*-ray tube² with an interchangeable anticathode. These photographs and accompanying optical and goniometric studies³ showed no features incompati-

² C. J. Ksanda, *Rev. Sci. Instr.*, **3**, 351, 1932.

³ Slightly inclined and irregular extinctions are seen through cleavage surfaces in the plane of which our measurements show the birefringence of the crystals from Italy to be only 0.0008. Slight strain-birefringence would account for observed irregularities of extinction, especially on different steps of a cleavage face, and the weak birefringence would account for other discrepancies in recorded optical orientation. Narrow whole blades supported edgewise in a liquid of refractive index β showed no divisional suture, and only a slight waviness from parallel extinction. (See "Conclusion" for other new measurements.)

A crosswise cleavage on ten blades (Italy) gave a patch of signals about 3° broad normal to the elongation, *c*-axis.

A hypothetical single monoclinic crystal with a beam of *x*-rays incident in any azimuth normal to the *b*-axis would give a Laue pattern of spots symmetrical with respect to the trace of (010), but not with respect to a line parallel to the *b*-axis.

ble with orthorhombic symmetry,³ therefore calculations for unit cell dimensions, a_0 , b_0 , c_0 , were carried out as shown in Table 2. The corresponding axial ratios are, $a:b:c=0.839:1:0.429$.

TABLE 2

DIMENSIONS OF THE UNIT CELL OF BAVENITE a_0 , b_0 , c_0 , CALCULATED FROM MEASUREMENTS ON FILMS FROM OSCILLATION AND ROTATION PHOTOGRAPHS

h, k, l	d/n	a_0	h, k, l	d/n	b_0
(100)	9.663	9.663	(010)	11.525	11.525
(200)	4.842	9.684	(030)	3.846	11.538
(300)	3.219	9.657	(040)	2.880	11.520
(400)	2.417	9.668	(050)	2.305	11.525
(500)	1.935	9.675	(060)	1.922	11.532
(600)	1.612	9.672	(070)	1.648	11.536
(700)	1.384	9.688	(080)	1.442	11.536
	$a_0=$	9.67Å	(090)	1.283	11.547
(001)	4.949	4.95Å= c_0		$b_0=$	11.53Å

By flotation, duplicate measurements of density of four very clear crystals from Italy gave 2.74₅.

The volume of the unit cell, and the density indicate that one chemical molecule,¹ $9\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot \text{BeO} \cdot 4\text{CaO} \cdot \text{H}_2\text{O}$, is associated with the unit cell of bavenite.⁴

X-ray reflections indicate that this unit cell is referable to the simple orthorhombic lattice type Γ_0 , and is isomorphous with one of the space groups V^1 , V_h^1 , or C_{2v}^1 .

A hypothetical pair of monoclinic crystals twinned on (100), the supposed twinning of bavenite (old orientation), would yield a double set of spots having both these elements of symmetry. The zone ellipses through the corresponding spots of the two crystals would be tangent at the center, but because of the inclination of the a -axis the two sets would not be spaced properly, except along the b -axis, so that it could be interpreted as a set of spots from a single crystal. With rays incident along the b -axis the prominent zone ellipses of a hypothetical single monoclinic crystal would have an unsymmetrical distribution of spots, and a twinned pair would yield a general pattern symmetrical with respect to two lines at right angles through the center, but the zone ellipses of one crystal would intersect the corresponding ones of the other. Thus the two sets could not be interpreted as a set from a single crystal.

No analogous double pattern was found on the other types of photographs.

⁴ Using mol. wt. = 909.8, and unit mol. wt. = 1512.1×10^{-24} g, the density calculated from x-ray data is 2.741.

CONCLUSION

Bavenite is here described⁵ in a new orthorhombic orientation with $a:b:c=0.839:1:0.429$; unit cell dimensions: $a_0=9.67$ Å, $b_0=11.53$ Å, $c_0=4.95$ Å, with one molecule of $9\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot \text{BeO} \cdot 4\text{CaO} \cdot \text{H}_2\text{O}$; density = 2.74₅; habit, blades which are elongated and striated parallel to the c -axis and flattened parallel to (010). Several subparallel parts joined edge to edge may have side dome faces in common. Cleavage (100) perfect, (001) fair. Colorless. Optical orientation:⁶ $\gamma = a = Bx_a$; $\alpha = c$; $+2V = 46^\circ - 58^\circ$ ⁵ without notable dispersion; $\beta - \alpha = 0.0007-8$, $\gamma - \beta = 0.005_0$; $\alpha_D = 1.583-4$,⁵ $\beta_D = 1.585$,⁵ $\gamma_D = 1.590$.

⁵ Original description, E. Artini, *Atti. Acc. Lincei*, **10** (2), 139, 1901. Optical determinations, E. S. Larsen, *Bull. U. S. Geol. Survey*, **679**, 44, 1921. General and detailed descriptions, W. T. Schaller, J. G. Fairchild.¹ The data are from our observations, except $2V = 58^\circ$ by Ross¹ on crystals from California. Birefringences were measured directly. Both α and β are 0.003–0.006, and γ is 0.000–0.007 higher than previous values.

⁶ Dr. Schaller wishes said: "A reexamination of the crystals from Italy shows that the optical orientation as given by me is wrong. The axial plane is parallel to the elongation and to the large face— $a(100)$ of the former orientation—essentially as given by Artini."

THE OCCURRENCE OF STRONTIANITE AT SIERRA MOJADA, MEXICO

PHILIP KRIEGER, *Columbia University.*

ABSTRACT

Strontianite is found in unusual abundance as a gangue mineral associated with lead and silver ores at Sierra Mojada, Mexico. The occurrence differs in several respects from other mineralization in this district. So far as known, strontianite has not been observed as a gangue mineral, even in minor amounts, in any of the ore bodies previously mined. In the Suiza ore body, however, it is sufficiently common as a gangue mineral to require hand sorting in order to separate it from the lead and silver ores. The strontianite is distinctly secondary in its occurrence and is believed to have been formed as an alteration product of celestite, the strontium sulphate. In the case of the celestite, however, the evidence appears to indicate that it was deposited by ascending hydrothermal solutions associated with ore deposition in the Suiza area.

INTRODUCTION

Sierra Mojada is located in the extreme western part of the State of Coahuila just a few miles east of the Chihuahua boundary. It is accessible by railroad over the Mexican Northern Railway, a branch line connecting with the Mexican National Railway at Escalon.

The district was first discovered in June 1878.¹ Since then the mines in the vicinity have been worked almost continuously and the district has been credited with having produced approximately five million tons of ore.² The ores consist chiefly of oxidized lead, silver and zinc minerals with some siliceous copper ores carrying rather high values in silver. The deposits are of the manto type* occurring in limestone and dolomite. Ore deposition appears to have been controlled largely by nearly east-west shear planes and fissures as well as certain favorable horizons in the limestone.

Sincere appreciation is extended to Mr. Henry Holcombe, superintendent, and Mr. F. L. Wingfield, geologist, for the many courtesies extended the author while visiting the property and for valuable information concerning the geology of the district. Mr. Van

¹ Chism, Richard E., Sierra Mojada, Mexico: *Trans. Am. Inst. Min. Eng.*, vol. 15, pp. 542-587, 1886-87.

² Hayward, M. W., and Triplett, W. H., The Occurrence of Lead-Zinc Ores in Dolomitic Limestone in Northern Mexico: *Trans. Am. Inst. Min. Eng.*, Technical Publication No. 42, 1931.

* The nearly flat-lying limestone replacement deposits of northern Mexico containing oxidized ores are usually referred to as "manto" deposits.

Dyne Howbert, of the American Metal Company, kindly gave his permission to publish the results of this study. Acknowledgment is also made to Professor R. J. Colony, of Columbia University, for helpful suggestions in the interpretation of criteria observed in thin sections.

GENERAL GEOLOGY

The earliest account of the geology of the Sierra Mojada district is by Chism,³ who apparently visited the camp shortly after its discovery. Later, Malcomson⁴ gave a comprehensive description of its history and development and the character of the ore deposits. Van Horn⁵ described the silver, copper and lead ores of the Veta Rica Mine and has noted the occurrence of several rare minerals in the district. The most recent work has been done by Hayward and Triplett⁶ who discuss the influence of dolomitic horizons in the limestone with relation to ore deposition.

The rocks making up the Sierra Mojada Range consist of a series of Lower Cretaceous limestone and dolomite beds dipping gently to the southeast and having a total thickness of approximately 3000 feet. The valley on the north side of the range has been partially filled with a flow of volcanic agglomerate over which has been deposited a considerable thickness of alluvial material. Strong thrust faulting, striking nearly due east and west and dipping about thirty degrees to the north, has forced the agglomerate against the limestone in a number of places along the north side of the range. Probably as a result of this faulting parallel shear planes were developed in the limestone, and where these intersect certain favorable horizons they have usually made important ore bodies which also have a general east-west trend.

Previous to the discovery of the Suiza ore body, most of the ore had been derived from these nearly east-west mantos. They have produced a variety of minerals, some of which are unusual in deposits of this type. Among these are such minerals as erythrite,

³ *Op. cit.*

⁴ Malcomson, J. W., The Sierra Mojada, Coahuila, Mexico, and its Ore Deposits: *Trans. Am. Inst. Min. Eng.*, vol. 32, pp. 100-139, 1902.

⁵ Van Horn, Frank R., The Occurrence of Silver, Copper and Lead Ores at the Veta Rica Mine, Sierra Mojada, Coahuila, Mexico: *Trans. A.I.M.E.*, vol. 43, pp. 219-233, 1912; A New Occurrence of Pearceite, *Amer. Jour. Sci.*, vol. 31, pp. 518-524, 1911; A New Occurrence of Silver, Copper and Cobalt Minerals in Mexico: *Amer. Jour. Sci.*, vol. 35, pp. 23-30, 1913.

⁶ *Op. cit.*

pearceite, descloizite, wulfenite and covellite, in addition to the many normal oxidation products of lead, silver, zinc and copper. Most of these have been described and can be found in the literature. Gangue minerals commonly associated with the ores consist of calcite, quartz, limonite, dolomite, gypsum and sulphur, and in some areas fairly large quantities of barite have been noted. So far as known, however, nowhere in any of these east-west mantos have strontianite and celestite been observed as a gangue mineral.

OCCURRENCE OF THE STRONTIANITE

Strontianite is found in considerable abundance throughout the length of the Suiza ore body, a distance of approximately 3500 feet.

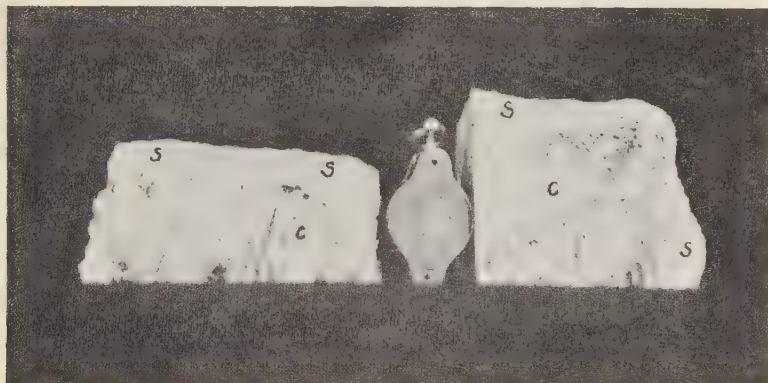


FIG. 1. Specimens showing the alteration of celestite (c) to strontianite (s). The strontianite forms a crust over the celestite and also penetrates between celestite crystals.

The mineral is also found in the Upper Atalaya ore body, a small area lying above and slightly to the east of the Suiza ore body. According to Mr. F. L. Wingfield, geologist at Sierra Mojada, recent development work appears to indicate that these two ore bodies will eventually connect with each other, so that they can be considered essentially as one ore body. The strontianite occurs in fairly large masses made up of innumerable fine crystals which rarely exceed five or six millimeters in length, and may sometimes resemble a white powdery mass. The mineral is distinctly secondary in its occurrence and is often associated with anglesite and cerussite, usually filling interstitial spaces between these oxidation

products. Chert nodules showing replacement by strontianite are frequently found included within large masses of the latter mineral. These probably represent residual chert, the surrounding limestone having been completely replaced by later strontianite.

The strontianite appears to have been formed by the alteration of celestite, the strontium sulphate, and perhaps to some extent as an alteration product of calcite. This alteration is well shown by the specimens in Fig. 1, the bulk of which consists of thin, tabular crystals of celestite having the characteristic bluish tinge and responding to the optical and chemical tests for this mineral. Strontianite forms a white, cloudy and somewhat botryoidal crust over

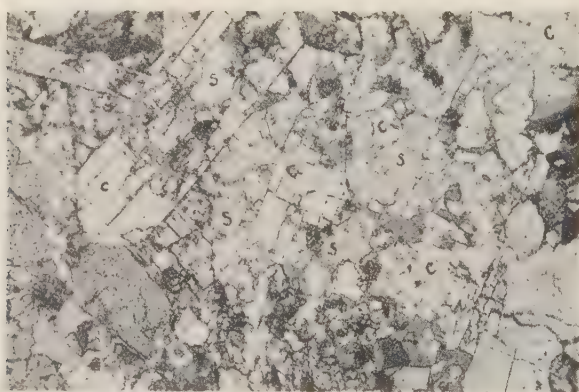


FIG. 2. Photomicrograph showing celestite (c) being replaced by strontianite (s). Strontianite also fills areas between celestite crystals. Nicols partially crossed. $\times 22$.

the celestite as well as penetrating through and between the celestite crystals. The same process can be seen in thin sections showing well formed euhedral crystals of celestite which have been partially replaced by strontianite, with the latter mineral also filling areas between celestite crystals.

The presence of such a large quantity of strontianite, and its apparent confinement to the one ore body in this district, presents a rather interesting problem in limestone replacement deposits. The general nature and occurrence of the strontianite indicate that it is undoubtedly a secondary mineral and there is sufficient evidence to show that most of it, at least, was formed by the alteration of celestite. In the case of the celestite, however, the evidence appears to favor a hydrothermal origin. This brings up the question

of primary sulphate minerals associated with ore deposits that was discussed by Butler⁷ some years ago. He cites numerous occurrences with conclusive evidence that such minerals as barite, alunite and anhydrite are undoubtedly primary constituents in some mineral deposits. Landes⁸ and Spence⁹ have both recorded the occurrence of celestite which they believe to be of hydrothermal origin rather than concentrated by the action of meteoric waters. The occurrence of primary celestite, however, is not nearly so common as in the case of barite or alunite. On the other hand, celestite formed by

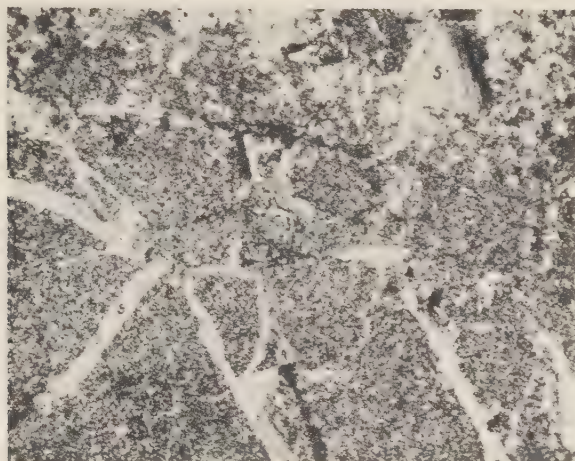


FIG. 3. Photomicrograph showing strontianite (s) filling fractures in and replacing a chert nodule. Crossed nicols. $\times 22$

the action of meteoric waters or other surface agencies has been noted by a number of writers.¹⁰

In the case of the Suiza ore body at Sierra Mojada it appears that strontium solutions were an important constituent of the same

⁷ Butler, B. S., Primary Sulphate Minerals in Ore Deposits: *Econ. Geol.*, vol. **14**, pp. 581-609, 1919.

⁸ Landes, Kenneth K., The Strontium Occurrence Near La Conner, Wash.: *Amer. Min.*, vol. **14**, pp. 408-415, 1929.

⁹ Spence, H. S., Barium Deposits of Canada: *Canada Mines Rept.*, p. 100, 1922.

¹⁰ Kraus, E. H., Occurrence of Celestite Near Syracuse, N. Y.: *Amer. Jour. Sci.*, 4th ser., vol. **18**, pp. 30-39, 1904; Occurrence and Distribution of Celestite-bearing Rocks: *Amer. Jour. Sci.*, 4th ser., vol. **19**, pp. 286-293, 1905; Kraus, E. H., and Hunt, W. F., The Occurrence of Sulphur and Celestite at Maybee, Mich.: *Amer. Jour. Sci.*, 4th ser., vol. **21**, pp. 237-244, 1906.

solutions responsible for primary ore deposition, and that celestite was quite likely a primary mineral deposited from these solutions. The evidence upon which this conclusion is based is as follows: (1) The confinement of both strontianite and celestite to the Suiza ore body and the absence of these minerals in other ore bodies of the district. If either strontianite or celestite were originally contained in the surrounding limestone and concentrated by meteoric waters, they would be expected to occur in other ore bodies of the district which have had a similar history as regards supergene processes. (2) Celestite is one of the early minerals of the deposit. No evidence was found which indicated that celestite replaces any of the older minerals. On the other hand, there is abundant evidence showing celestite being replaced by such oxidation products as anglesite and cerussite as well as by strontianite. (3) The celestite occurs in greater abundance associated with residual masses of primary ore, such as galena which has been but partially oxidized to anglesite and cerussite, and with such gangue minerals as quartz and barite. Where oxidation has been more prominent and the primary sulphide ores have been altered to anglesite and cerussite, the celestite has also been destroyed and its place taken by strontianite. This evidence is more easily interpreted as being due to ascending hydrothermal solutions associated with the late stages of metallic mineral deposition.

If both strontianite and celestite were secondary minerals, they would be expected to occur in a similar manner. The strontianite, however, is distinctly secondary, much of it having been formed even after the oxidation of galena to anglesite and cerussite had been accomplished, whereas the celestite is obviously earlier than the period of oxidation.

SOME PROPERTIES OF AUTHIGENIC TOURMALINE FROM LOWER DEVONIAN SEDIMENTS

STELLA WEST ALTY, *Saskatoon, Canada.*

INTRODUCTION

Authigenic tourmaline has been observed as a secondary growth on small detrital grains of tourmaline in Lower Devonian rocks from oil-wells in the Lower Peninsula of Michigan.¹ More recently it has been noted in the Lower Monroe dolomite from the quarry of Messrs. France Stone Co., in Monroe County, Michigan. Similar grains of tourmaline with an authigenic portion have been described from the Oriskany Sandstone of several of the eastern states of America.²

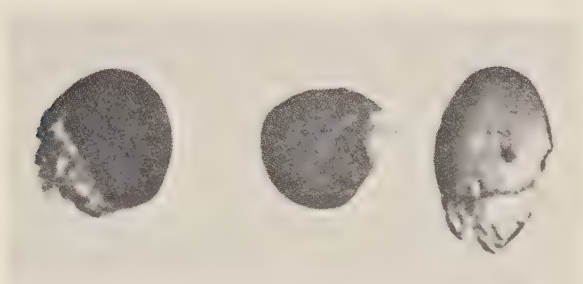


FIG. 1. Detrital grains of tourmaline with secondary growth ($\times 100$).

Typical grains of this tourmaline from the Lower Devonian rocks of Michigan are shown in Fig. 1. The authigenic portion is colorless while the original grain is colored and strongly pleochroic. In Fig. 1 one grain is in the position of minimum and two in the position of maximum absorption. The rounded outline of the original grain is in marked contrast to the angular margin of the colorless authigenic portion. The latter is in complete optical continuity with the original grain and always occurs at one end of the *c*-axis of the grain.

The properties of this authigenic tourmaline have been investigated further and the results obtained are described below.

¹ Alty, Stella West, *Proc. Mich. Acad. of Science, Arts and Letters*, p. 289, vol. 18, 1932.

² Stow, Marcellus H., *Am. Min.*, vol. 17, p. 150, 1932.

REFRACTIVE INDEX

The refractive indices of tourmaline vary according to the chemical composition of the mineral, being highest in the deeply-colored varieties which are rich in iron and manganese, and lowest in the colorless tourmalines. Hence in the case of the grains here described there should be some difference between the refractive indices of the colorless authigenic portion and the colored original grain. Measurements of the refractive indices were accordingly attempted; such determinations are difficult owing to the small size of the grains. The latter are rarely greater than 0.2 mm. in diameter and the authigenic portion generally forms less than half of any one grain. Refractive index tests could only be carried out by immersion of the grain in a liquid of known refractive index.

The procedure was as follows: Samples of heavy minerals containing authigenic tourmaline were examined microscopically, in air, and a tourmaline grain picked out on a needle point. The grain was then immersed in a liquid of suitable refractive index, examined under the microscope in sodium light and the refractive index of the mineral observed to be either higher or lower than that of the liquid. Immediately after this observation was made, the refractive index of the liquid was determined on a small refractometer in sodium light.

A number of such tests were made, using different grains of tourmaline and various refractive index liquids. The method of immersion is not highly accurate but very consistent results were obtained. The orientation of the authigenic tourmaline is known at once by comparison with the original grain with which it is in optical continuity and which shows the ordinary pleochroism of colored tourmaline. Consequently the directions of the ordinary and extraordinary rays of the authigenic tourmaline are known with certainty, and the refractive indices can be obtained in these two directions.

It was impossible to make more than one observation on one grain. A grain could be picked out in air and immersed in a liquid but it could not be transferred from one liquid into another; indeed it was usually "lost" when some of the liquid in which it was immersed was taken for refractive index determination on the refractometer. Consequently a different grain was used for each determination but the results obtained were completely consistent and it was found possible to determine the refractive indices within

narrow limits. Thus the index of refraction of the ordinary ray was clearly less than 1.630 and greater than 1.626; the mineral was practically invisible in liquid of refractive index 1.628. Similarly when examined by means of the extraordinary ray the authigenic tourmaline was almost invisible in liquid of refractive index 1.610.

In every case the index of refraction of the authigenic tourmaline was found to be considerably lower than that of the original grain. The refractive indices of the latter varied considerably, as was to be anticipated; that of the ordinary ray was always greater than 1.635 and that of the extraordinary ray varied between 1.620 and 1.635.

The refractive indices of the authigenic tourmaline are remarkably low, even for colorless tourmaline; it is believed that they are the lowest recorded for this mineral. The lowest values given by Dana³ and the lowest recorded by Ward⁴ are given in the following table:

	Variety	ω	ϵ	$\omega - \epsilon$
Dana	colourless	1.636	1.6193	0.0167
Ward	white	1.640	1.614	0.026
Alty	colourless	1.628	1.610	0.018

PYRO-ELECTRIC ORIENTATION

It is one of the characteristics of the authigenic tourmaline here considered that it always occurs as a secondary growth on one end of the *c*-axis of the original grain, and an attempt has been made to determine upon which end of this axis the crystallization has occurred.

The pyro-electric properties of tourmaline indicate that when heated the grains must develop opposite surface electrification at opposite ends; if discharged at the high temperature and allowed to cool they must develop an equal electrification but with reversed polarity. If the polarity of the electrification could be determined the orientation of the authigenic tourmaline with reference to the *c*-axis would be known.

The charge developed on a pyro-electric crystal is proportional to

³ Dana, J. D., *System of Mineralogy*, 6th Edition, p. 553.

⁴ Ward, G. W., *Am. Min.*, vol. 16, p. 151, 1931.

the cross section of the crystal and consequently in the case of very tiny grains the charge is so small that it is very difficult to carry out any tests. Various methods have been attempted but the following is the only one which proved at all successful.

The tourmaline grains (with grains of other heavy minerals) were heated for a few minutes on a metal plate over a Bunsen flame. The grains were then brushed onto a microscope slide; moving them over the metal plate in this way would effectively neutralize their surface charge. After allowing them to cool for a few moments a tourmaline grain was examined under the microscope. On cooling the grain would develop a new pyro-electric charge on its surface, and the nature of this charge was investigated by observing the effect produced on the grain by (a) electrified glass and (b) electrified sealing wax.

(a) A glass rod drawn out to a fine tip was rubbed vigorously on silk in order to give it a positive electric charge. The tip of the rod was gently introduced into the field of view of the microscope and it was found that the glass rod attracted the end of the grain opposite to the authigenic tourmaline, i.e., the colored end. The behavior of the grain varied according to the direction of approach of the glass rod; if the rod approached towards the colored end of the grain the latter jumped towards the rod slightly and adhered to it; if the rod approached the opposite end, i.e., the colorless authigenic end, the grain remained inert until the rod practically touched it, and then it turned in such a way as to bring the colored end of the grain against the rod. In some cases the charge on the grain was not large enough to make it turn towards the glass, but in this case the colorless authigenic end was inert towards the rod while the colored end would adhere to it sufficiently for the grain to be pulled across the field of the microscope by it. The electric charge on the grains was soon discharged in air and consequently clear results could only be obtained very shortly after the grains had been heated and cooled down. After standing in air for several minutes they were usually quite "dead" and gave no evidence of bearing on electric charge.

(b) Obviously if the colored end of the tourmaline was attracted to a positively charged glass rod the opposite end should be attracted to a substance which bears a negative charge. Experiments were carried out with a rod of sealing wax instead of glass, the wax being rubbed upon fur to give it a negative charge. The results how-

ever, were very unsatisfactory. The wax appeared to develop so large a charge when it was rubbed upon fur that when introduced into the microscope field it attracted *all* grains on the slide, the tourmaline included. The pyro-electric charge on the grains was evidently completely masked by the charge induced by the electrified wax.

The results, however, obtained with the glass rod were very consistent and were repeated many times. Consequently this seems fairly conclusive evidence that these grains, on being discharged and then cooled, develop a negative charge on the colored end of the grain which is attracted to the positively charged glass rod. This is, therefore, the analogous pole of the mineral and the authigenic tourmaline is formed at the other end, the antilogous pole, which is characterized crystallographically by the faces $r(10\bar{1}1)$ and $m(10\bar{1}0)$.

SUMMARY

The refractive indices of authigenic tourmaline occurring as a secondary growth on detrital grains of tourmaline have been determined. The indices of refraction are unusually low, being:

$$\omega = 1.628$$

$$\epsilon = 1.610$$

An examination of the pyro-electric properties of the compound grains indicates that the authigenic portion is invariably found at that end of the c -axis which is the antilogous pole of the mineral.

NOTES AND NEWS

BROWN TOURMALINE FROM FRONTENAC AND RENFREW COUNTIES, ONTARIO*

G. A. HARCOURT, *Queen's University.*

A massive block of a brown mineral was found on the dump of an abandoned mica pit which was sunk on a pegmatite cutting Grenville limestone on lot 5, con. 10, Portland tp., Frontenac Co., Ontario. On breaking this block open striated crystal faces were exposed which adjoined one another in a manner suggesting genicular twinning.

A similar mineral was collected by Drs. E. L. Bruce and J. E. Hawley from Lyndoch tp., Renfrew Co., which occurred in distinct crystals showing a second order prism and first order positive rhombohedron-like faces.

These minerals have been determined as varieties of magnesium and calcium tourmaline. Since these varieties of tourmaline have been reported from only one or two localities in Ontario, the following description is given.

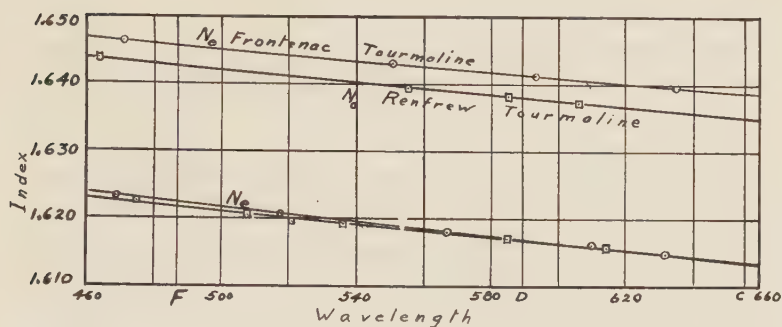
PHYSICAL CHARACTERISTICS. Color, dark brown, except on thin edges where they are a light yellowish brown. Hardness 7, vertical striations are common. Absorption $O > E$. Pleochroism: In

OPTICAL PROPERTIES—Uniaxial, negative

	Frontenac tourmaline	Renfrew tourmaline
N_o	1.6415	1.6382
N_e	1.6170	1.6168
$N_o - N_e$	0.0245	0.0214
$N_F - N_C \quad N_o$	0.0072	0.0080
$N_F - N_C \quad N_e$	0.0093	0.0085

a section .06 mm. thick, E = very light brown, almost colorless; O = yellowish brown. The indices determined for light of different wavelengths by the double variation method of Emmons are as follows:

* Published by permission of the National Research Council of Canada.



The chemical composition of tourmaline having these optical properties has been taken from charts prepared by A. N. Winchell.¹

Frontenac tourmaline

81.8% $\text{H}_8\text{Na}_2\text{Mg}_6\text{B}_6\text{Al}_{12}\text{Si}_{12}\text{O}_{62}$
 11.1% $\text{H}_8\text{Na}_2(\text{Fe}, \text{Mn})_6\text{B}_6\text{Al}_{12}\text{Si}_{12}\text{O}_{62}$
 6.2% $\text{H}_8\text{Ca}_2\text{Mg}_8\text{B}_6\text{Al}_{10}\text{Si}_{12}\text{O}_{62}$
 0.9% $\text{H}_8\text{Ca}_2(\text{Fe}, \text{Mn})_8\text{B}_6\text{Al}_{10}\text{Si}_{12}\text{O}_{62}$

Renfrew tourmaline

54% $\text{H}_6\text{Ca}_2\text{Mg}_8\text{B}_6\text{Al}_{10}\text{Si}_{12}\text{O}_{62}$
 46% $\text{H}_8\text{Na}_2\text{Mg}_6\text{B}_6\text{Al}_{12}\text{Si}_{12}\text{O}_{62}$

The sodium molecule predominates in the Frontenac tourmaline and it is properly called dravite. The Renfrew tourmaline contains a much greater proportion of the calcium molecule, according to this chart, and is best named uvite.

The chemical constituents of the minerals have been checked with the aid of a quartz wedge spectrograph and a comparison made with the common iron tourmaline of the district, and a specimen of dravite from Dobrawa, near Unterfrouburg in Karnten, Germany. The major and minor constituents are listed below along with the intensity of the corresponding lines obtained in the spectrum of the minerals. The intensities are given in an arbitrary scale ranging from 1 to 10 and do not represent percentages. The intensities are of value however, in comparing dravite and schorlite and in separating the major from the minor constituents.

	Si	Al	Ca	Mg	Na	B	Fe	Sr	Mn	Ti	Cr	V
Frontenac Co.	10	5	9	10	3	9	4	2	Tr	1	Tr	Tr
Renfrew Co.	10	5	8	10	3	9	4	—	—	—	4	Tr
Dobrawa	10	5	2	10	3	9	4	—	—	Tr	Tr	Tr
Schorlite	10	5	8	6	4	9	9	—	6	2	2	1

¹ A. N. Winchell, Ferrotremolite, Oxyhornblende, and Tourmaline: *Am. Mineral.*, vol. 17, No. 10, 1932, p. 475.

The spectrographic analyses, without laying any claim to accurate quantitative results, show a considerable proportion of calcium in the two brown tourmalines collected and indicate that the chemical composition of both are very similar, except for the appreciable amount of chromium shown by the crystals from Renfrew Co., and the persistent occurrence of strontium in the Frontenac dravite. Strontianite is associated with the Frontenac specimen but thorough washing in hot HCl failed to remove the strontium, reported above, from the mineral.

The above determinations were made in the Miller Research and Mineralogy laboratories, Queen's University, Kingston, Ont., in connection with an investigation of the minor constituents of some granites, conducted with the aid of a scholarship granted by the National Research Council of Canada.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, April 6, 1933.

President Trudell presided at a meeting of the society on April 6th, 43 members and 32 visitors being present. Members elected were: J. Wallace Rowland, Jr., and Martin D. Fetherolf; also the following juniors: Albert H. Klein, John A. Bulat, Joseph F. Szulc, Hamilton S. Disston, Raymond Beatty, R. Keith Anderson, Frank Fink, and Bertram Fitzgerald.

Dr. Waldemar T. Schaller of the United States Geological Survey spoke on "The Mineralogy of a Potash Mine near Carlsbad, New Mexico." Geological details were presented, illustrated with charts, lantern slides, and specimens. He emphasized the enormous reserves of polyhalite, sylvite, and carnallite present in the area.

Mr. Morgan reported finding natrolite, analcite, and other minerals at Millington, N. J., and agate and crystal cavities at Prospect Park. Other trips were described by Mr. Toothaker, Dr. Wills, and Mr. Gudehus.

W. H. FLACK, *Secretary*

NEW MINERAL NAMES

Ashcroftine

MAX H. HEY AND F. A. BANNISTER: Studies on the Zeolites. Part IV. Ashcroftine (kalithomsonite of S. G. Gordon). *Min. Mag.*, **23**, 305-308, 1933, (cf. *Proc. Acad. Nat. Sci., Phila.*, **76**, 261, 1924).

NAME: In honor of Frederick Noel Ashcroft.

CHEMICAL PROPERTIES: A hydrous silicate of alumina, potash, soda, and lime. $\text{NaK}(\text{Ca}, \text{Mg}, \text{Mn})\text{Al}_4\text{Si}_5\text{O}_{18} \cdot 8\text{H}_2\text{O}$. (cf. kalithomsonite, *Am. Mineral.*, **10**, 132, 1925).

CRYSTALLOGRAPHICAL PROPERTIES: Tetragonal. $c=17.49 \text{ \AA}$. $a=34.04 \text{ \AA}$. Small needles bounded by the cleavage forms $a(100)$, and $c(001)$.

PHYSICAL PROPERTIES: $\epsilon=1.545$, $\omega=1.536$. Sp. Gr.=2.61, ± 0.05 .

W. F. FOSHAG

Gumucionite

ROBERT HERZENBERG: Gumucionit, eine neue arsenhaltige Varietät der Schalenblende (Gumucionite, a new arsenic bearing sphalerite). *Centr. Min. Geol.*, Abt. A, pp. 77-78, 1933.

NAME: For Julio F. Gumucio, chief engineer at Llallagua, Bolivia.

CHEMICAL PROPERTIES: An arsenical sphalerite. Zn 64.73, S 32.75, As 0.64, Fe 0.27, Cd tr., H_2O 1.28, insol. 0.52. Sum 100.19.

PHYSICAL PROPERTIES: Color raspberry red, dirty rose red, sometimes somewhat brownish; streak pale yellow. Sp. Gr.=3.76. H=somewhat greater than 4. Isotropic.

OCCURRENCE: Found as kidney-shaped, concentric laminated and radiated aggregates, later than cassiterite, quartz, pyrite, etc.

REMARKS: A sphalerite colored by realgar.

W. F. F.

DIRECTORY OF AMERICAN AND CANADIAN MINERAL COLLECTIONS

SAMUEL G. GORDON, *Academy of Natural Sciences of Philadelphia*.

(Continued from page 324)

KANSAS

BALDWIN CITY BAKER UNIVERSITY.

A general collection of 5776 specimens is in custody of Mr. E. J. Cragoe in the Museum and Science Hall, and may be seen on Wednesday afternoons on application.

EMPORIA COLLEGE OF EMPORIA.

KANSAS STATE NORMAL SCHOOL.

LAWRENCE UNIVERSITY OF KANSAS.

A collection of 500 specimens is displayed in Haworth Building. The systematic collection of 1500 minerals may be seen by application to the custodian, Dr. Kenneth K. Landes. The collections contain many specimens from the Tri-state lead and zinc district, the Black Hills, Magnet Cove, and Llano Co., Texas.

LINDSBORG BETHANY COLLEGE.

MANHATTAN KANSAS STATE AGRICULTURAL COLLEGE.

MCPHERSON MCPHERSON COLLEGE.

SALINA KANSAS WESLEYAN UNIVERSITY.

TOPEKA WASHBURN COLLEGE, MUSEUM OF NATURAL HISTORY.

KENTUCKY

BOWLING GREEN OGDEN COLLEGE.

COVINGTON BAKER-HUNT FOUNDATION: WILLIAMS NATURAL
HISTORY COLLECTION, MUSEUM AND LIBRARY.

The systematic collection of Mr. G. N. Hobbs (curator) is installed in the
Museum.

DANVILLE CENTRE COLLEGE OF KENTUCKY.

FRANKFORT KENTUCKY GEOLOGICAL SURVEY.

Part of the Survey collections are exhibited in the Mines Building, open
daily from 8 A.M. to 12 M., and 1 P.M. to 4 P.M.

LEXINGTON TRANSYLVANIA UNIVERSITY.
UNIVERSITY OF KENTUCKY.

Part of the collections of the Kentucky Geological Survey are housed at the
University.

LOUISVILLE LOUISVILLE PUBLIC LIBRARY MUSEUM.

Contains the collection of Gerard Troost, the first American crystallographer,
the Octavia Allan Shereve memorial cabinet, and part of the J. Lawrence Smith
collection.

RUSSELVILLE BETHEL COLLEGE.

LOUISIANA

BATON ROUGE LOUISIANA STATE UNIVERSITY.

A general collection of 2000 specimens is open to visitors Monday to Friday,
8 A.M. to 5:30 P.M. Minerals from the cap rock of salt domes (such as exposed in
the nearby Winnfield Quarry) are well represented.

NEW ORLEANS LOUISIANA STATE MUSEUM.
TULANE UNIVERSITY.

Mr. R. A. Steinmayer is custodian of the University's collection of 5000
specimens. The collection which may be seen by appointment includes the
Henry A. Ward collection of the New Orleans Exposition of 1884, and the
cabinet of the New Orleans Academy of Sciences.

MAINE

ANDOVER E. M. BAILEY.

A general and local collection of 2500 specimens.

W. D. NEVEL.

AUGUSTA KENNEBEC HISTORICAL SOCIETY, HALL LITHGOW
LIBRARY BUILDING.
MAINE STATE MUSEUM.

BRUNSWICK BOWDOIN COLLEGE.

The general collections in the Science Building (Department of Chemistry) and in custody of Prof. M. P. Cram, include the cabinets of Francis Alger, and George Warren Hammond. They may be seen weekdays. The Cleaveland cabinet in the Main Hall may be seen on application at the Dean's office.

BUCKFIELD PERIEN S. DUDLEY.

HOWARD M. IRISH.

EAST SUMNER WILSON BONNEY.

HINCKLEY BATES MUSEUM of the Good Will Homes and Schools.

LEWISTON BATES COLLEGE MUSEUM.

The collections of minerals and rocks were begun by Dr. F. T. Tubbs. Since 1929 they have been in charge of Dr. Lloyd W. Fisher. The collections consist of about 1000 specimens for student study; a collection of Maine minerals, especially pegmatite materials; the E. C. Rich collection; a special series of rocks from the Lewiston quadrangle; and fossils of the Eastport district. The collections, housed in the laboratory rooms, are open to the public 9-12 A.M. and 2-5 P.M. daily except Sundays. The displays are on the fourth floor of Carnegie Science Hall.

LIVERMORE MISS FLORENCE NELSON.

NORWAY GEORGE A. HOWE.

GEORGE NOYES.

ORONO UNIVERSITY OF MAINE.

The collection numbers 2000 specimens, with many specimens in storage for lack of space. The collection was founded by Lucius H. Merrill who furnished many of the rarer minerals.

PARIS HAMLIN MEMORIAL HALL, C. E. Sham, Librarian.

Three hundred specimens of tourmaline crystals and cut tourmalines from Mount Mica may be seen at any time on payment of 10 cents: in summer on Mondays from 2:30 P.M. to 4 P.M., on Wednesdays from 7:30 P.M. to 9 P.M., and in winter, on Wednesdays from 2:30 P.M. to 4 P.M. and 7:30 P.M. to 9 P.M.

PARIS HILL ARTHUR VALLEY.

Owens collection of the late Loren B. Merrill.

PORTLAND GEORGE S. BLACK, 19 Atlantic Street.

PHILIP C. FOSTER, Westminster Avenue.

HERBERT M. HAVEN, 500 Forest Avenue.

M. L. KEITH, 151 Pleasant Street.

A local collection.

H. WALLACE NOYES, 83 West Street.

A collection of 1000 general and local specimens.

PORTLAND SOCIETY OF NATURAL HISTORY MUSEUM, A. H. Norton, Curator.

22 Elm Street. Open from 2 P.M. to 5 P.M. on weekdays. An extensive series of minerals is on exhibition. The earlier collection of minerals of C. H. Hitchcock was destroyed by fire in 1866.

RIDLONVILLE CHARLES F. MARBLE.

A local collection of 800 specimens.

THOMASTON KNOX ACADEMY OF ARTS AND SCIENCES: KNOX MUSEUM, Norman W. Lermond, Curator.

The museum, open every day of the week, houses a general collection of 2500 specimens.

WATERVILLE COLBY COLLEGE.

WEST PARIS STANLEY PERHAM.

MARYLAND

ANNAPOLIS MARYLAND GEOLOGICAL SURVEY COLLECTION.

In part, in the State House.

U. S. NAVAL ACADEMY.

BALTIMORE GOUCHER COLLEGE, Museum.

JOHNS HOPKINS UNIVERSITY.

Contains some specimens of the Maryland Geological Survey, as well as the O. D. Allen Collection.

MARYLAND ACADEMY OF SCIENCES.

Contains the Ferdinand C. Chatard, and E. A. Dalrymple collections.

UNIVERSITY OF MARYLAND

ELLICOTT CITY ROCK HILL COLLEGE.

PYLESVILLE BENNET C. WHEELER.

A general collection of 4000 specimens.

WESTMINSTER WESTERN MARYLAND COLLEGE.

MASSACHUSETTS

AMHERST AMHERST COLLEGE.

The collections, which include the cabinets of Francis R. Allen, Charles U. Shepard (minerals and meteorites), Edward B. Underhill, and the third collection of George Frederick Kunz, are housed in the Geology-Biology Building. Dr. Frederick B. Loomis is custodian. It may be seen daily from 8 A.M. to 6 P.M., and in summer by application to the college guide.

MASSACHUSETTS AGRICULTURAL COLLEGE.

Museum of Zoology and Geology.

BOSTON

BOSTON SOCIETY OF NATURAL HISTORY. 234
Berkeley Street.

Edward Wigglesworth, Custodian. The Museum contains a remarkable display of New England minerals, with 150 species represented in the 10,000 specimens. Early collections acquired by the Society included those of Charles T. Jackson, J. E. Teschermacher, and Thomas T. Bouve. The museum is open daily from 9 A.M. to 4.30 P.M., and on Sundays from 1.30 P.M. to 4.30 P.M.

BOSTON UNIVERSITY, Commercial Museum.

CHILDREN'S MUSEUM. Olmstead Park, Jamaica Plain.

Mildred E. Manter, Director. About 1500 mineral specimens are exhibited daily from 9 A.M. to 5 P.M., Sundays from 1.30 to 5 P.M. (closed Thanksgiving and Christmas). A large collection now in storage will be exhibited in a new building.

CAMBRIDGE

HARVARD UNIVERSITY, Mineralogical Museum.

Professor Charles Palache, Curator. The exhibits include: (1) an outstanding crystal collection, (2) a systematic series (in part), (3) unusual specimens of gem minerals: tourmaline, beryl, topaz, etc., (4) a suite of minerals from Franklin, New Jersey, (5) a group of huge gypsum crystals, and (6) a large meteorite collection. The principal mineral collection is that of the late Albert F. Holden (who had purchased the Losey collection of Franklin minerals), bequeathed to the university with an endowment fund. Other Harvard collections include the Liebner collection, the Elwood P. Hancock cabinet, containing choice specimens from Franklin and Tilly Foster—crystals worked out of the matrix with unrivalled skill and artistry, the Stanton collection (Franklin minerals), the G. Flink collection, in part, of Langban minerals; the Augustus Hemlin collection of tourmalines, the Garland gem minerals, the M. Bellow collection of minerals from Portugal and Portuguese colonies, the F. Ahlfeld collection of Bolivian minerals, the Bigelow agates, and the Clarence Bement collection (in part) of minerals in box mounts for the microscope; also the J. Lawrence Smith collection of meteorites. Only a part of these are exhibited.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
69 Massachusetts Ave.

A collection of 5000 specimens is maintained for teaching and research.

CHESTNUT HILL

BOSTON COLLEGE (University Heights), Museum in Science Building.

Minerals are exhibited in three cases.

CONWAY

MRS. EDWARD KOEBER.

Collection of her grandfather, the late Henry A. Weeks of Chesterfield, Mass.

DOVER DOVER HISTORICAL AND NATURAL HISTORY SOCIETY.

FALL RIVER PUBLIC LIBRARY.

Contains the collection of James G. Manchester (in part); numbering about 3000 specimens, and including many choice Erie cut minerals.

FITCHBURG MRS. F. W. PIERCE, 82 Summer Street.
WALLACE LIBRARY AND ART BUILDING.

George E. Nutting, Librarian. A case of minerals, presented by John H. Daniels, may be seen from 9 A.M. to sunset on weekdays, and from 1.30 P.M. to 4 P.M. on Sundays.

FRAMINGHAM HISTORICAL AND NATURAL HISTORY SOCIETY.
FRANKLIN J. W. BAKER, R.F.D. 2, Box 8.

A general collection of 2600 specimens including many from Rhode Island. (He purchased the Silas Carr and Eddy-Racine collections.)

GLOUCESTER CAPE ANN SCIENTIFIC AND LITERARY ASSOCIATION.

LEOMINSTER LEOMINSTER PUBLIC LIBRARY-MUSEUM, West Street.

Florence E. Wheeler, Custodian. A general collection in 6 cases is exhibited daily from 9 A.M. to 9 P.M.

MARLBOROUGH MARLBOROUGH SOCIETY OF NATURAL HISTORY.

MARION MARION NATURAL HISTORY SOCIETY.

MILTON A. B. WILBOUR, 200 Blue Hill Parkway.

NORTHAMPTON SMITH COLLEGE.

A collection of 7000 specimens is housed in Seelye Building. Included are the Hitchcock, Clark, and Morganthau collections.

PITTSFIELD MUSEUM OF NATURAL HISTORY AND ART.

Contains the Daniel Clark Collection.

SALEM PEABODY MUSEUM.

A. P. Morse, Curator. Although the collection of over 5000 specimens is a general one, Essex County minerals are fully represented. The Museum is open daily.

SOUTH HADLEY MOUNT HOLYOKE COLLEGE.

A fire some years ago destroyed all of the collections. A new collection, which already numbers 1000 specimens is on exhibition, and may be seen when the college is in session. The collection is housed in the Clapp Laboratory.

SPRINGFIELD MUSEUM OF NATURAL HISTORY.

TAUNTON BRISTOL COUNTY ACADEMY OF SCIENCES.

TUFTS COLLEGE TUFTS COLLEGE: BARNUM MUSEUM.

A general collection of 8000 specimens.

WELLESLEY SHELLEY W. DENTON, 24 Denton Road.

A general and local collection of several thousand specimens. Specializes in gem minerals.

WELLESLEY COLLEGE.

Contains the Horace I. Johnson Collection of New England Minerals.

WILLIAMSTOWN WILLIAMS COLLEGE.

Teaching collections of several thousand specimens are maintained in Clark Hall, and may be seen daily by appointment. Prof. H. F. Cleland is Custodian.

WORCESTER CLARK UNIVERSITY, Educational Museum.

COLLEGE OF THE HOLY CROSS

MRS. H. W. GODDARD, 190 Salisbury Street.

Collection of the late H. W. Goddard.

WORCESTER NATURAL HISTORY MUSEUM.

MICHIGAN

ADRIAN ADRIAN COLLEGE.

ALBION ALBION COLLEGE.

ALMA ALMA COLLEGE, HOOD MUSEUM OF NATURAL HISTORY.

H. M. MacCurdy, Director. The exhibits include the Alexander Winchell collection of 6000 specimens of minerals, rocks, and fossils.

ANN ARBOR UNIVERSITY OF MICHIGAN, Natural Science Building.

Dean Edward H. Kraus, Director. The University collections are located in Room 2071, and comprise a general systematic collection (including the Lederer cabinet, principally of European minerals), a gem collection of natural crystals and cut stones, a collection of polished slabs of architectural and decorative stones, a collection of Michigan rocks and minerals, and a crystal collection. The room is open to visitors daily, except Sundays and Holidays, from 8 A.M. to 5 P.M.

BATTLE CREEK MUSEUM OF NATURAL HISTORY OF THE BATTLE CREEK PUBLIC SCHOOLS.

BLOOMFIELD HILLS CRANBROOK INSTITUTE OF SCIENCE.

C. A. Newcomb, Jr., and William B. Colburn, Curators of Minerals. The Museum, endowed by Mr. and Mrs. George Booth in 1929, is located in the Institute of

Science Building of the Cranbrook Foundation, and is 12 miles distant from Detroit. It is open daily from 9 to 5 except on Saturdays and Sundays. Showy minerals, particularly from Michigan, are featured.

DETROIT CHILDREN'S MUSEUM, 96 Putnam Street.

Gertrude A. Gillmore, Curator. A small mineral collection may be seen on weekdays and Sunday afternoons.

EAST LANSING MICHIGAN STATE COLLEGE.

S. G. Bergquist, Custodian. A general collection, rich in Michigan minerals, may be seen on application.

GRAND RAPIDS KENT SCIENTIFIC MUSEUM.

H. E. Ward, Curator. A general collection of 2000 specimens.

HILLSDALE HILLSDALE COLLEGE.

HOUGHTON MICHIGAN COLLEGE OF MINING AND TECHNOLOGY, Mineralogical Museum.

An extensive series of minerals, with many remarkable specimens of calcite and copper from the Michigan copper mines.

J. T. REEDER, 318 College Avenue.

A collection of 2500 mineral specimens, including choice Michigan minerals.

KALAMAZOO KALAMAZOO PUBLIC MUSEUM AND ART INSTITUTE.

DuPortal D. Porter, Curator of Minerals. Exhibits include part of the private collection of Mr. Porter. Open daily, except Sunday, from 2 to 5.

DUPORTAL D. PORTER.

A large general collection, the nucleus of which was the collection of Charles Miller (Grand Rapids).

PORT HURON PUBLIC LIBRARY, MUSEUM.

SAGINAW FRED DUSTIN, 705 S. Fayette Street.

A collection containing an extensive series of Isle Royale semi-precious gems, and similar materials from drift, Indian village sites, or river beds.

ST. JOHNS J. D. JANES.

About 700 specimens, mostly from the southwestern States.

THREE OAKS CHAMBERLAIN MEMORIAL MUSEUM.

Harold Barton, Custodian. A general collection of 1500 specimens, specializing in Lake Superior iron and copper minerals. Open every day, except Sunday.

(To be continued)

BOOK REVIEWS

CRYSTALLOGRAPHY, MINERALOGY, STRUCTURES, extracted from Volumes VIII (1927-1928) and IX (1929) of the ANNUAL TABLES OF CONSTANTS, PROFESSORS NIGGLI AND BRANDENBERGER (ZURICH) AND MATHIEU (PARIS). 223 pages, 22 cm./28 cm. Price, bound Frs. 100 (\$3.91). Publishers, Gauthier-Villars & Co., 55 Quai des Grands Augustins, *Paris*.

The extreme importance of these complete tables to the research worker is clearly indicated by the statement that their preparation required the careful examination and systematic classification of data collected from more than 650 scientific journals.

The section of special interest to mineralogists is that portion, separately bound and comprising 223 pages, that records the new data in the fields of crystallography, mineralogy and crystal structure. Drs. P. Niggli and E. Brandenberger have compiled the material relating to mineralogy, and the crystallography of minerals and artificial compounds, both organic and inorganic. Measurements which merely confirm previous results but do not exceed them in accuracy have been omitted from the Tables, as well as optical determinations on insufficiently defined substances, except when accompanied by chemical analyses. For new mineral species all observed forms and symbols are given, but for previously known minerals only the absolutely new forms are recorded. The chemical data have been quoted fully.

The portion devoted to crystal structure, compiled by Dr. M. Mathieu, lists for each substance: crystal system; length of unit cell edges; angles between the cell edges; the experimental and calculated density; number of molecules in the unit cell; and the space group according to Schönflies-Asbury or that of Wyckoff.

W.F.H.

PROSPECTING AND OPERATING SMALL GOLD PLACERS. WILLIAM F. BOERICKE. Published by John Wiley and Sons, Inc., *New York*.

This small volume of 132 pages, devoted to the timely subject of the recovery of gold from placer deposits, has been prepared to assist the man without technical education, in prospecting and operating placers efficiently with a minimum investment for equipment.

The simple geology of placers, the common methods of prospecting employed in their discovery, and the methods and mechanical means necessary for the separation and recovery of the gold are successively treated in a very readable, non-technical manner. Inclusion of data relative to the operation of dry placers, and the use of placer mining machines, which may be operated by one or two men where water is available is of interest. A discussion of the legal location of a claim, sale of gold, and sale of a placer property increases the usefulness of the volume.

This handbook will be found decidedly useful to those with sufficient optimism to engage in the search for gold. The price is \$1.50.

W. M. MYERS

REPORT ABOUT THE MINES IN THE UNITED STATES OF AMERICA, 1783. SAMUEL GUSTAF HERMELIN. Translated from the Swedish by Amandus Johnson. The John Morton Memorial Museum, Philadelphia, 1931. 76 pp., 1 plate.

In 1783 Hermelin visited America to investigate the "geology and the purification of metals"; after 148 years his report is published for the first time. The work constitutes the first one on the mineral resources of this country. It preceded by four years the well known Schoepf's "Beiträge zur mineralogischen Kenntniss des östlichen Theils von Nord-Amerika und seinen Gebirge" (1787), usually considered the first book on American minerals.

With the exception of certain general geological and botanical notes, only iron ore deposits and mines are described: "In some parts of the United States of America, rich iron ores are obtained at cheap prices on account of the nature of the ore quarries . . ." "The majority of the iron ore fields hitherto exploited are situated in the following three states: New Jersey, . . . Pennsylvania, . . . Maryland . . . In addition a few mines are worked in other states . . ." Among the mines described are those of Hibernia, Mount Hope, Succasunny and Andower in New Jersey; and Durham, Warwick, Jones, Hopewell, and Cornwall in Pennsylvania. The translator's unfamiliarity with geological terms results in the use of "sweep" where "strike" should have been used.

SAMUEL G. GORDON